Climate Change Fuel Cell Program for
PC25 FUEL CELL

Final Report for the U.S Department of Energy

Covering Field Experience
from
October, 2001 to September, 2002

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ABSTRACT

Since August, 2001, an International Fuel Cells (IFC) PC25 C self-contained fuel cell has been applied to provide the prime power to the air handling units (AHUs) and heat to the domestic hot water for the Lied Jungle in the Henry Doorly Zoo at Omaha, Nebraska.

This report details the application of the fuel cell plant at the Lied Jungle. Information is provided on the resulting electrical and thermal productions, as well as availability, reliability factors, and cost parameters.

Some concerns about the reliability for the unstable power load application and the useful heat availability of the high grade heat recovery, at partial power operations, are discussed.

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INTRODUCTION

As part of its ongoing research on distributed generation technologies, OPPD installed an International Fuel Cells (IFC)'s PC25 C Fuel Cell power plant to provide electricity power and heating energy to the Lied Jungle in the Henry Doorly Zoo (HDZ) at Omaha, Nebraska in 2001.

Product Description of the PC25C Fuel Cell (1)

The IFC's PC25 C power plant is a factory assembled self-contained fuel cell with continuous electrical rating of 200 kW/235 kVA (280 Volts, 3 phase, and 60 Hz).

The useful heat can be applied to heat customer hot water through the high grade (if 250°F hot water is preferred) and low grade (if 140°F hot water is preferred) energy recovery units. For domestic hot water applications, to prevent the potential of coolant contact with domestic water, a double-walled heat recovery heat exchanger can be applied. At rated power, the standard PC25 C power plant provides more than 700,000 Btu per hour to heat a customer water stream to a temperature of 140°F. The estimated availability of heat is rated load as a function of customer water supply and return temperature. (Appendix A presents how the fuel cells work)

The fuel cell has high electricity efficiency, beginning of life greater than 40%. Overall efficiency is over 85% with use of heat recovery (based on the manufacture's performance data). And the availability is normally over 99%.

The phosphoric acid fuel cell is a completely automatic commercial power plant designed for unattended outdoor operation.

Application at the Lied Jungle

The Lied Jungle is the world's largest indoor tropical rainforest. Covering 1.5 acres directly inside the Main Gate, the Lied Jungle® Building has 61,000 square feet of exhibit space. The building's height of 80 ft. is about the same as an 8-story building. Materials include fiberglass, concrete and metal frameworks. The roof, constructed of fiberglass-reinforced plastic, allows natural light to penetrate the rain forest.

Mechanical devices not native to a jungle, such as air ducts, filters and light fixtures, are hidden in the walls and rocks.

There are two Air Handling Units (AHUs) serving the space air conditioning. Each AHU has one supply fan and one return fan. All motors are operated at Variable Frequency Drive (VFD) to achieve the variable air flow when the cooling or heating load is off the design peak load.

Figure 1: Lied Jungle

The fuel cell plant is applied in a grid independent application to provide the prime electricity power to all four (4) fans which serve the two Air Handing Units (AHU) and two (2) pumps with the local utility grid applied as the back up power source.

The high grade heat energy is applied to heat the domestic water up to 180°F in the existing hot water heat exchanger (or call hot water storage tank) with the existing boiler system applied as the back up heat source.

The low grade heat is applied to preheat the make-up water in a new make-up water storage tank of the domestic hot water system. The domestic hot water is mainly used for animal cage cleaning. Figure 2 shows the diagram of the fuel cell plant at the Lied Jungle.

The zoo was chosen for the project for five main reasons:

- The jungle previously was served by two 60-kilowatt co-generation units, which the zoo removed because of high maintenance costs. The piping for the natural gas supply and heat recovery left over from these removed units will be placed back into service for the fuel cell.
- The jungle has a good 24-hour load factor, which means it requires a substantial amount of electricity around the clock. Figure 3 presents the actual daily power load profile. The peak load is approximately 172 kW and the minimum load is approximately 80 kW.
- The jungle can use the heat rejected by the fuel cell year around to heat the domestic hot water which is used for jungle cleaning.
- The zoo is located fairly close to Energy Plaza, the home base of the OPPD employees who operate and maintain the unit.
- The zoo provides a highly visible location for an educational display on fuel cells.

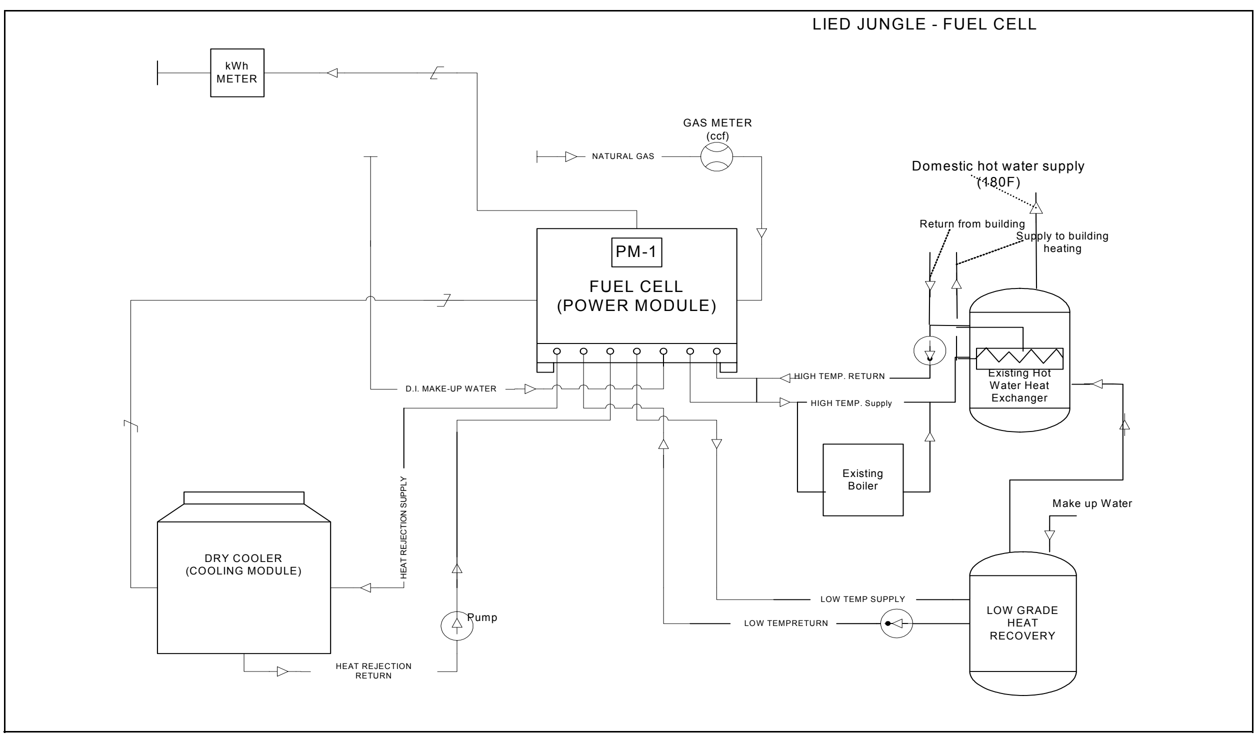


Figure 2: Diagram of the Fuel Cell Plant at the Henry Doorly Zoo

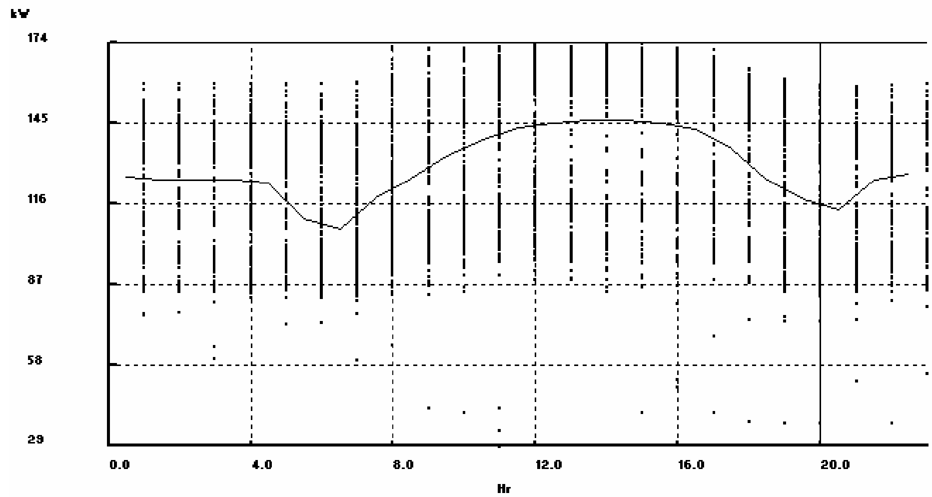


Figure 3: Average Daily Electricity Load Profile

Note: The average daily power load profile (the curve in the figure) is calculated based on the hourly data from October 3, 2001 to September 30, 2002.

EXECUTIVE SUMMARY

Fuel cells are an environmentally clean (low emission), quiet and highly efficient method for generating electricity and heat from natural gas and other fuels. A number of customers and utility industry have indicated interest in fuel cell technology and application in meeting future customer and grid needs. Led by the Omaha Public Power District (OPPD), with the support of the Electric Power Research Institute (EPRI) and the U.S. Department of Energy (DoE), this program is demonstrating the use of a International Fuel Cells (IFC)'s 200 kW PC25 Model C fuel cell in a variable power load application.

This report provides the information of the application of the IFC's 200 kW PC25 Model C fuel cell at the Lied Jungle in the Henry Doorly Zoo at Omaha, Nebraska and provides the results of the availability, reliability, energy efficiency, and cost parameters. Some concerns about the heat recovery are discussed.

The operation performance results show that the annualized availability is 74%, mean time between forced outage is 713 hours, electricity efficiency is 36%, overall efficiency is 38% with the heat recovery, and capacity factor is 38%.

The values of most of the parameters are lower than the manufacture's specifications. These are due to multiple factors.

The low annualized availability and mean time between forced outage were mainly caused by the grid voltage fluctuations and the gas leakage problem in gasket of HO valve on starting gas circuit line. To eliminate the grid voltage fluctuations affect on the fuel cell operation and allow the fuel cell to run on its own internal clock, the grid synchronizer was disconnected in December, 2001. The availability is significantly improved (over 95%) in the second half year after the two main issues were resolved.

The low overall efficiency is due to two reasons: 1) the actual high grade hot water temperature from the fuel cell is much lower than the temperature specified at rated power. Consequently, there is little opportunity to recover the high grade heat energy. 2) The actual make-up water load seems low. The low grade energy recovery unit can not fully be utilized, even though the low grade heat energy is available.

The low capacity factor is due to nature of the variable power load of the variable air volume AHUs.

The total project capital cost is $1,285,796.00 which includes equipment cost, engineering services, and installation cost. The first year operation and maintenance cost is $19,900 per year. Energy operation cost (natural gas cost) is $26,422.20 per year. Then, the annualized unit operation cost is $0.0708/kWh. The annualized unit operation cost for subsequent years will be lower because the unscheduled O&M cost is expected to be greatly reduced from the current year because most of the operating issues have been successfully resolved.

To improve the operation performance, the following are recommends:

- A further research on the heat energy recovery properties at partial loads is essential for the manufacture, since it is important to the customers with variable power loads.

- An investigation is required for OPPD to identify additional potential opportunity to utilize heat energy recovery from the low grade energy recovery unit.

EXPERIMENTAL

The objective of the experiment is to measure the basic parameters which are used to derivate the results requested by the U.S. Department of Energy (DOE) for the final report. The required results include availability, Mean Time between Forced Outages (MTBFO), energy (natural gas) consumption, energy productions (electricity and heating energy recovery), efficiency and load capacity of the fuel cell.

The metered basic parameters are natural gas energy consumption, electricity power output, and heating energy recovery.

Figure 4 presents the components of the metering system installed on the fuel cell. They are a gas meter, an electricity meter, and two BTU meters. The table below provides the meter information.

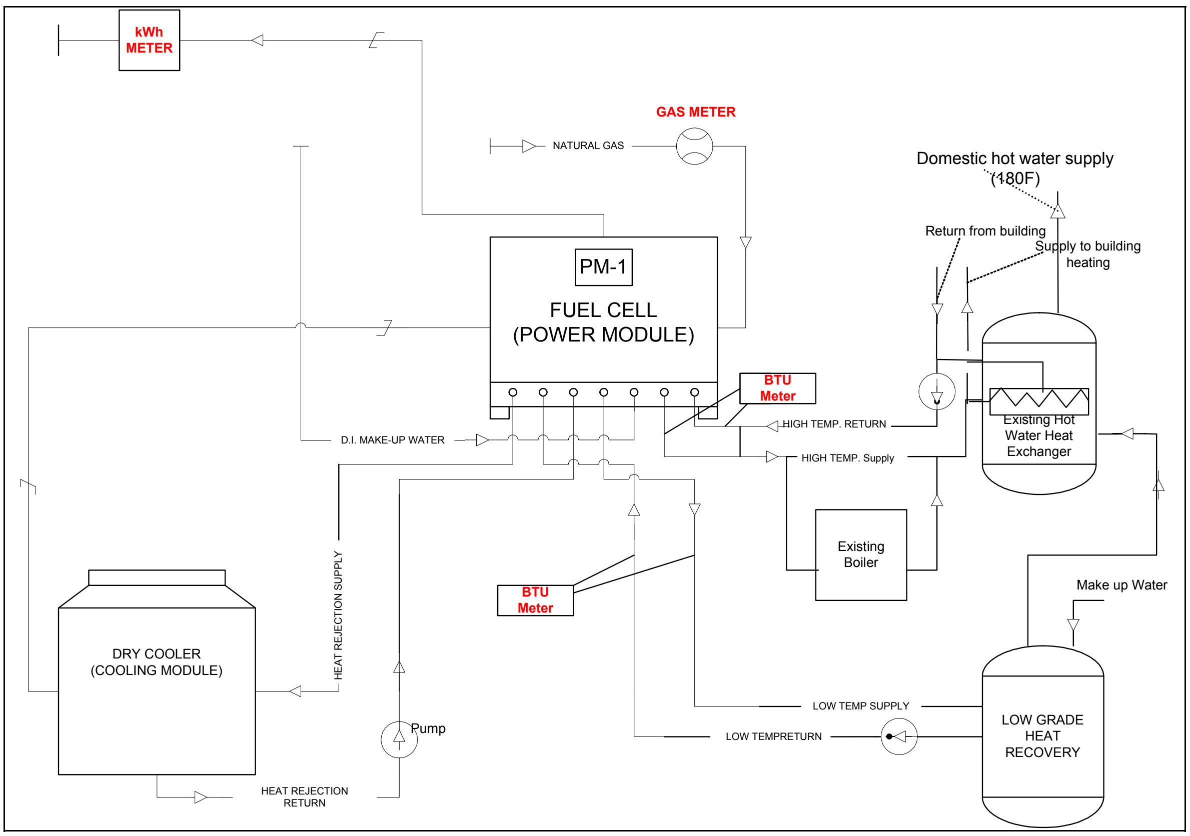


Figure 4: Metering System for the Fuel Cell

Table 1: Meter information

Meter	Manufacture	Model #-Series #	Accuracy
Electricity Meter	GE	GEH-5081B kV	+/-0.2%
Gas Meter	Measurement Operation Dresser Equipment Group, Inc.	3M175 Series B3	+/-1%
BTU Meter	NIAGARA	7431-1	+/-0.5%

The gas, electricity, and energy recovery data are collected on monthly basis and are used to determine the annual energy operation cost and efficiency. Since monthly data can not accurately provide the information of the availability and MTBFO, the hourly electricity data is monitored and recorded using Energy View Program developed by Elutions. The hourly electricity data provides the information regarding when the fuel cell starts and stops and how AHU load varies. This also provides valuable reference information for operation trouble shooting. The hourly electricity data and some instant temperature data displayed on the BTU meters provide useful information to investigate the availability of the heating energy recovery at different partial loads. fuel cell starts and stops and how AHU load varies. This also provides valuable reference information for operation trouble shooting. The hourly electricity data and some instant temperature data displayed on the BTU meters provide useful information to investigate the availability of the heating energy recovery at different partial loads.

RESULTS and DISCUSSION

Mean Time between Forced Outage

Two measures of reliability are particularly useful: Availability and Mean Time between Forced Outage (MTBFO). Availability is simply the percentage of overall calendar time that the unit is operating. MTBFO is the length of time the unit can be expected to operate once it is running.

Table 2 presents the historical on/off hours, availability, and MTBFO.
The on/off hours are counted based on the hourly monitored power output data (see Figure 5). The causes of the shutdown are reported from the project engineer. The overall availability is 74%. MTBFO is 713 hours.

Table 2: Availability and Mean Time Between Forced Outage (MTBFO) Results

Record No.	Startup	Shutdown	Operation Hours	Off Hours	Availability	Average MTBFO Hours
1	10/3/2001	10/21/2001	427	629		
2	11/16/2001	11/20/2001	97	504		
3	12/11/2001	1/24/2002	1058	263		
4	2/4/2002	3/15/2002	931	677		
5	4/12/2002	4/30/2002	431	47		
6	5/2/2002	5/22/2002	481	23		
7	5/23/2002	5/24/2002	19	103		
8	5/28/2002	6/30/2002	792	21		
9	7/1/2002	9/30/2002	2208			
Overall	**10/04/2001**	**9/30/2002**	**6421**	**2267**	**74%**	**713**

Notes:
The actual start up date of the fuel cell is August 22, 2001. The stipulated start up date in this report is October 03, 2001 due to a lack of good energy data before this date. However, the causes of the shut downs for this period are recorded and are reported in this report, since the experiences during the first two months are very important to the manufacture and the future fuel cell users.

Table 3 summarizes the major causes of the shutdowns. The three longest shut down periods (see Figure 5) were mainly caused by the grid voltage fluctuations which occurred before December, 2001 and the gas leakage problem in gasket of HO valve on starting gas circuit line which occurred before the middle of April, 2002. The voltage fluctuations appear due to the high inrush demand caused when the voltage of the grid dropped to below 460V and then immediately returned to 480V. The fuel cell would follow the load by closing the fuel valve but could not respond instantaneously to the inrush demand requirements of 480V. The inrush would spike to over 200 kW.

To eliminate the grid voltage fluctuations effect on the fuel cell operation and allow the fuel cell to run on its own internal clock, the grid synchronizer was disconnected in December, 2001. The availability is significantly improved (over 95%) in the second half year after the two main issues ware resolved.

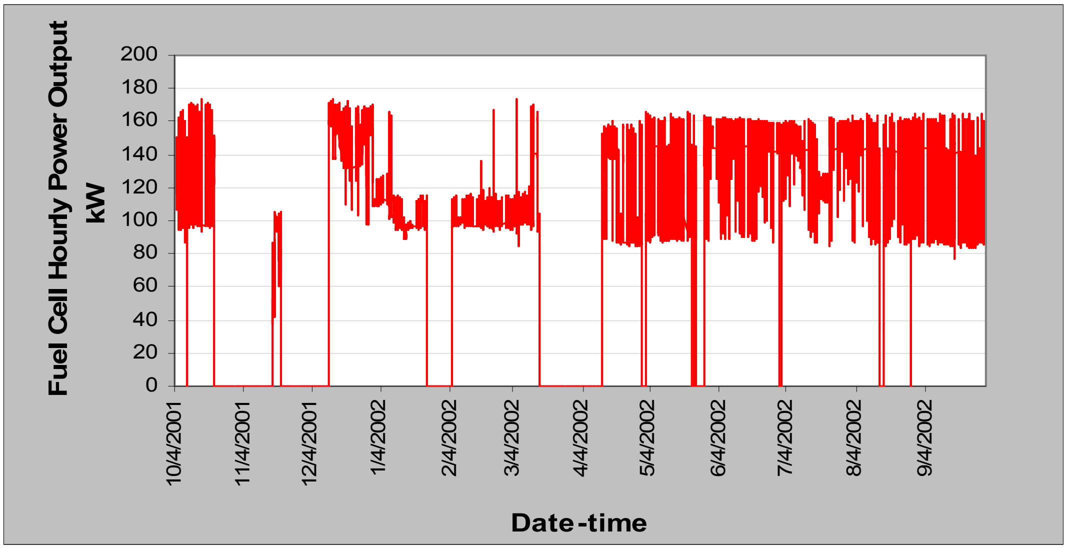


Figure 5: Historical Hourly Electricity Power Output Data of the Fuel Cell Plant

Table 3: Major Causes of the Shut Downs

Record No.	Shutdown	Startup	Descriptions of the Causes
1	8/22/01	10/03/01	The fuel cell plant was shut down nine (9) times. The major causes are the failures of the valve FPS-CV-500, the OPPD grid switching, VFD drives, and fan contactor failure on one of the dry cooler fan motors.
2	10/21/2001	11/16/2001	Fluctuation of the grid voltage which was caused by turning on the pump motors. The investigation took about one month.
3	11/20/2001	12/11/2001	Fluctuation of the grid voltage. The investigation took another 20 days. Finally, the problem is resolved by disconnecting the grid synchronizer.
4	1/24/2002	2/4/2002	Due to (1) an overtime run on make up water pump #451; (2) cracked fuel regulating valve; (3) trip heat trace circuit breaker; (4) low inverter voltage caused by stating a 20 hp fan motor. (5) Communication board and software problems (guess).
5	3/15/2002	4/12/2002	Gas leak detected in gasket of HO valve on starting gas circuit line. Wind damaged temperature probe of the cabinet ventilation systems.
6	4/30/2002	5/2/2002	N/A
7	5/22/2002	5/23/2002	Due to low burner air caused by plugged fresh air filter.
8	5/24/2002	5/28/2002	Due to low burner air apparently caused by the brake failure on air processing system flow control valve (FCV140).
9	6/30/2002	7/1/2002	The fuel cell knocked down when the Zoo personnel started a motor and the fuel cell was operating at about 50% load.

Energy Operation Performance Parameters

The fuel cell energy operation performance parameters in this report include production of the fuel cell, efficiency, and capacity factor.

Productions of the fuel cell plant are electricity and heat energy recovery. The efficiencies include the overall efficiency (outputs are electricity and heating recovery) and electricity efficiency (not including the heating recovery).

Productions and Efficiency

Table 4 presents the monthly gas energy consumption, electricity production, heating recovery through heating recovery units, and calculated efficiency.

Table 4: Fuel cell Energy Consumption and Productions

Mon	Gas Consumption Therm	Electricity kWh	Heat Recovery kBtu	Overall Efficiency (incl. ele. and heating)	Ele. Efficiency (ele only)
Oct-01	5180	53778	16337		
Nov-01	980	7521	7945		
Dec-01	6930	71086	36219		
Jan-02	5430	60015	52211		
Feb-02	6860	60205	44923		
Mar-02	2550	37223	6113		
Apr-02	5170	51591	6176		
May-02	8010	73862	12151		
Jun-02	9190	102361	3627		
Jul-02	10090	102065	1627		
Aug-02	8680	95359	2337		
Sep-02	8438	91558	380		
Annual	**62,910**	**653,767**	**190,044**	**38%**	**36%**

Notes: The gas data are collected from the gas bills. The other data are calculated based on the hourly monitoring data.

The annual electricity production is 653,767 kWh and the heating recovery is 190,044 kBtu. The annual gas consumption is 62,910 therms. The overall efficiency is 38% and the electricity efficiency is 36%. The capacity factor is 38%.

The heating energy recovery of 190,044 kBtu per year is much lower than the energy recovery availability specification (700 kBtu/hr). The reasons of the low energy recovery are:

- The fuel cell does not operate at full load (200 kW). The energy recovery specification of 700,000 Btu/hr is rated at the full load operation. The actual load of the fuel cell ranges from 40% to 87%.

  The data shows that the supply water temperature from the fuel cell varies from 130°F to 160°F for the high temperature energy recovery. The supply water temperature is some time higher and sometime lower than the water temperature of the cell. Consequently, the hot heating system sometime recovers the heat from the fuel cell and sometime rejects heat to the fuel cell.

- The domestic water load seems lower than what we expected. The supply water temperature from the fuel cell ranges from 110°F to 140°F which are recoverable since it is higher than the make-up water temperature (approximately 50°F). However, the observations from the site visits and the monitored data showed that the pump is in the off mode most of time.

Capacity Factor

The capacity factor since start up is the total output divided by the maximum potential output.
The total output, from October 4, 2001 to September 30, 2002, is 653,767 kWh and the maximum potential output is 1,737,600 which are production of total hours (8688 hours) and nameplate output capacity of 200 kW. The capacity factor then is 38%.

Cost Parameters

The cost parameters in this report include fuel cell plant installation cost and operation cost. The plant installation costs consist of the equipment cost and field installation cost. The operation costs are the fixed operation cost which includes operation/maintenance cost and variable operation cost which is operation energy cost.

Plant Installation Cost

The total project cost is $1,285,796.00. Table 5 presents the cost breakdown of the plant installation, which includes the equipment cost, field installation cost, and engineering consulting cost.

Table 5: Cost Breakdown of the PC25 C Fuel Cell Plant at OPPD

Item	Cost ($)
200kW- PC25 C Fuel Cell (factory assembled and self-contained)	$841,902.00
Mechanical Installation	$59,977.00
Engineering Consulting	$81,071.00
Transfer Switch	$28,116.00
General Fuel Cell Installation	$274,730.00
Total Cost	**$1,285,796.00**

Notes: The PC25 fuel cell cost of $841,902.00 includes the grant of $200,000 awarded by DOE. Therefore, actual fuel cell cost to OPPD is $641,902.00.

Operation Costs

The operation and maintenance for the plant involves two components: scheduled and unscheduled services. Scheduled maintenance for the plant consists of such items as: replacing or cleaning filters, rebuilding pumps, and replace consumables. Quarterly maintenance includes the change out of water treatment cylinders, filters, and the like.

Unscheduled Maintenance is the response to a forced outage. Thus, unscheduled maintenance can include both the labor and parts cost components.

The total annual O&M cost to OPPD is $19,900/year. The operation labor cost of $800/year (20 hours/year) is involved from routine site visits. The unscheduled O&M cost of $19,100/year includes payroll costs for coordination with the manufacturer, vendor, and site visits for resolution of operating problems. The unscheduled O&M cost for subsequent years is expected to be greatly reduced from the current year because most of the operating issues have been successfully resolved.

The average fixed operating unit cost is $0.0304/kWh, which is calculated based on the total O&M cost of $19,900/year and total electricity production of 653,767 kWh/year.

The operation energy cost is the gas fuel cost. The gas fuel cost is calculated based on the actual monthly gas utility bills from Metropolitan Utility District (the local gas company). The gas usage data is collected directly from the gas meter of the fuel cell plant. The total annual gas usage is 62,910therms/yr and the cost is $26,422.20/yr (the gas rate schedule is attached in Appendix B). The unit energy operation cost is 9.62KBtu/kWh and $0.0404/kWh, which is calculated based on the total gas utility cost and the total electricity production.

Therefore, the annualized unit operation cost is $0.0708/kWh (which is a total of the annualized unit operation and maintenance cost of $0.0304/kWh and the annualized unit operation energy cost of $0.0404/kWh).

The average electricity rate of the fuel cell is $0.0611/kWh. The electricity rate schedule from OPPD (the local electricity utility company) is attached in Appendix C.

The table below lists the operation cost records.

Table 6: Fixed Operation Cost (Operation/Maintenance Cost)

Operation/Maintenance (O&M) Description	Cost ($)
Scheduled O&M:	
Regularly site visits (20 hours/year)	$800/yr
Replace or cleaning filters*	0
Rebuilding pumps*	0
Replace consumables*	0
Change out water treatment cylinders*	0
Unscheduled O&M:	$19,100/yr
Total Annual Cost	**$19,900/yr**

*No cost to OPPD since the maintenance is in the manufacture's warranty.

CONCLUSION

The values of most of the operation performance parameters are lower than the manufacture's specifications. These are due to multiple factors.

The low annualized availability and mean time between forced outage are mainly caused by the grid voltage fluctuation issue which occurred before the fuel cell grid synchronizer was disconnected and the gas leakage problem in gasket of HO valve on starting gas circuit line. The availability of over 95% was achieved in the second half year after resolving the two key issues.

The low overall efficiency is due to two reasons: 1) the actual high grade hot water temperature from fuel cell is much lower than the temperature specified at rated power. Consequently, there is little opportunity to recover the high grade heat energy; 2) the actual make-up water load seems low. The low grade energy recovery can not be fully utilized, even though the low grade heat energy is available.

The low capacity factor is due to the factors of nature of the variable power load of the variable air volume AHUs.

To improve the operation performance, the following are recommended:

- A further research on the heat energy recovery properties at partial loads is necessary for the manufacture to provide sufficient information for the customers with variable power loads.

- An investigation is required for OPPD to identify additional potential opportunity to utilize heat energy recovery from the low grade energy recovery unit.

ACKNOWLEDGMENTS AND REFERENCES

Purchase of this PC25 Model C fuel cell power plant has been founded by the Omaha Public Power District. Additional funding for this portion of the program has also supplied by the Electricity Power Research Institute and U.S. Department of Energy.

International Fuel Cells, the manufacture, has also provides valuable services.

Henry Doorly Zoo at Omaha, Nebraska provides the site and supports.

REFERENCES

1. *PC25 Power Plant Design and Application Guide*, developed by International Fuel Cells, LLC, 2001.

2. *NRECA Transportable Fuel Cell Program – Final Report for the U.S. Department of Energy*, prepared by Energy Signature Associates, inc, 1998.

Appendix A: How Does a Fuel Cells Work?

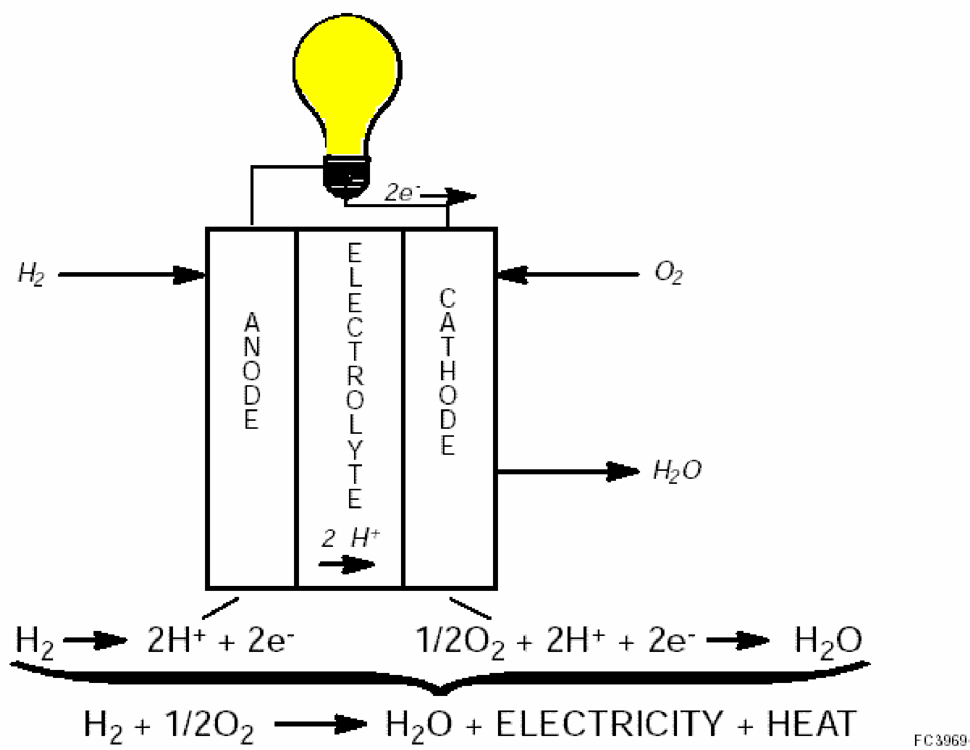
A fuel cell is an electrochemical device that combines hydrogen fuel and oxygen from the air to produce electricity, heat and water. Fuel cells operate without combustion, so they are virtually pollution free. Since the fuel is converted directly to electricity, a fuel cell can operate at much higher efficiencies than internal combustion engines, extracting more electricity from the same amount of fuel. The fuel cell itself has no moving parts - making it a quiet and reliable source of power.

The picture shows how a fuel cell produces electricity. The fuel cell is composed of an anode (a negative electrode that supplies electrons), an electrolyte in the center, and a cathode (a positive electrode that emits electrons).

As hydrogen flows into the fuel cell anode, platinum coating on the anode helps to separate the gas into protons (hydrogen ions) and electrons. The electrolyte in the center allows only the protons to pass through the electrolyte to the cathode side of the fuel cell. The electrons cannot pass through this electrolyte and flow through an external circuit in the form of electric current. This current can power an electric load, such as the light bulb shown here.

As oxygen flows into the fuel cell cathode, another platinum coating helps the oxygen, protons, and electrons combine to produce pure water and heat.

Individual fuel cells can be then combined into a fuel cell "stack". The number of fuel cells in the stack determines the total voltage, and the planform area of each cell determines the total current. Multiplying the voltage by the current yields the total electrical power generated.



Appendix B: Metropolitan Utility District Gas Rates

Commercial and Industrial Firm (Schedule B)

The base gas rate is the published rate, which includes both the service charge and the commodity charge.

1. Included in the base rate is an allowance for the cost to buy and transport natural gas to our service area. As the cost of gas varies from month to month, the commodity charge is adjusted to reflect the charges in the cost of purchased gas under the Purchased Gas Adjustment (PGA) provision in the published rate schedule.

2. The service charge covers costs for administration, such as meter reading, billing and collections. These are costs the District incurs by having the customer on-line, even if no gas is used by the customer. The service and commodity charges also include an allowance for a 2 percent statutory payment to cities.

   The actual cost of natural gas for the past 24 months is listed below.

24-Month Cost of Gas

Date	Commodity Charge (0-2,500 TH)	Commodity Charge (2,500+ TH)
10-02-2002	.4473 TH	.4373 TH
9-02-2002	.4146	.4046
8-02-2002	.3894	.3794
7-02-2002	.4144	.4044
6-02-2002	.4246	.4146
5-02-2002	.4300	.4200
4-02-2002	.4163	.4063
3-02-2002	.4078	.3978
2-02-2002	.3774	.3674
1-02-2002	.4357	.4257
12-02-2001	.4325	.4225
11-02-2001	.5080	.4980
10-02-2001	.3030	.2930
9-02-2001	.3587	.3487
8-02-2001	.4419	.4319
7-02-2001	.4419	.4319
6-02-2001	.5073	.4973
5-02-2001	.5860	.5760
4-02-2001	.6300	.6200
3-02-2001	.6689	.6589
2-02-2001	.8125	.8025
1-02-2001	$1.0764	$1.0664
12-02-2000	.7396	.7296
11-02-2000	.6236	.6136

Schedule B
Commercial and Industrial Firm Gas Service
Effective January 2, 2002
Supersedes Schedule B, effective July 1, 1999

Availability
This rate schedule is available to customers purchasing firm gas for commercial or industrial purposes, including space heating, under the following conditions:

1. When residential gas use is combined with commercial or industrial gas use on a single meter, all gas used will be classified as commercial or industrial.

2. Multiple housing customers having more than three dwelling units connected to a single meter, shall be considered commercial.

3. Gas space heating will not be authorized as supplemental heat for areas using other fuels for heating.

4. The total daily requirement for all gas uses shall not exceed 199,000 cubic feet per day.

5. District may require a customer to furnish daily meter readings for the purpose of monitoring the customer's gas load.

Large Volume Use
Loads in excess of 199,000 cubic feet per day must have special authorization from District General Manager.

Metering and Billing Units

District gas meters register in units of cubic feet.
For billing purposes, gas meters are read in units of either 100 cubic feet (Ccf) or 1,000 cubic feet (Mcf).

In most cases, the index readings from the meter can be directly applied in the billing process. In some instances, direct readings from the meter index require correction for pressure and/or temperature.

Some of the District's larger commercial/industrial meters are equipped with correction devices, including an additional index showing the corrected usage.

Supercompressiblity Adjustment
Due to the behavior of gas molecules under high pressures, additional correction to index readings in certain situations will be applied.

For example, meter readings for customers receiving gas metered at pressures equal to or greater than 40 psig or for customers receiving gas metered at pressures equal to or greater than 10 psig with annual usage of 50,000 Mcf or more, shall be adjusted for supercompressiblity.

The supercompressibility adjustment factor shall be specifically identified on the customer's monthly bill.

Billing Units
The billing unit under this rate schedule is a therm (100,000 British thermal units -- Btu).

The number of therms billed hereunder in any month shall be determined by multiplying the volume of gas in cubic feet by the average heating value of the gas, expressed in Btu per cubic foot as applicable for such month and dividing this product by 100,000.

Rate: Monthly Billing

	Nov.-March	April-Oct.
Service Charge:	$12	$12
Commodity Charge:		
First 2,500 therms	$.4897 TH	$.4377 TH
Over 2,500 therms	.4797 TH	.4277 TH

Purchased Gas Adjustment
Rates included herein are subject to adjustment for changes in cost of natural gas to District as provided for in gas rate "Schedule PGA-1, Purchased Gas Adjustment Provisions." For current billing rate and/or billing rate history, contact our Rate Division.

Minimum Monthly Bill
$12 net.

Statutory Payment to City
Under Nebraska Statutes, Section 14-2138 and 2139, R.R.S. 1997, the District is required to pay to each city or village 2 percent of retail sales of gas. Two percent has been included in the above rate on all bills to residents inside a city or village. Therefore, the rate for all customers residing outside corporate limits is 2 percent less than the rate indicated above.

Turn-on Charge
A turn-on charge will be required upon application for gas service.

Payment
The monthly bill will be rendered at the above net rate. If not paid within 15 days of date of bill, a gross bill of 4 percent higher than the net bill will be due and payable. An additional late payment charge of .5 percent per month will be charged on the portion of any account in arrears two or more months. In no event will the total late payment charge exceed 10 percent.

Emergency Priority
Gas service under this schedule is subject to curtailment to meet fuel requirements of higher emergency priority customers. Emergency priority customers shall be determined by the District or as directed by other governmental authority having jurisdiction.

Stranded Costs
Customers, who have received firm service for a period of three years or more and who convert to interruptible service or transportation service, shall be subject to the "stranded pipeline/supply costs" monthly charge as provided for under the District's rate "Schedule FT, Firm Gas Transportation Service."

This provision also shall apply where there has been continuous service for three years or more at the same service address under one or more ownership changes.

Appendix C: OPPD Electricity Rates

SCHEDULE NO. 231

GENERAL SERVICE - DEMAND

Availability:

To all Consumers throughout the District's Service Area.

The single phase, or three phase if available, alternating current, electric service will be supplied at the District's standard voltages, for all uses, when all the Consumer's service at one location is measured by one kilowatthour meter with a demand register, unless a Consumer takes emergency or special service as required by the District's Service Regulations. Not applicable to shared or resale service.

This rate is not available to those Consumers taking Irrigation Service as identified in Rate Schedule No. 226.

Net Monthly Rate effective January 1, 1998:

A Basic Service Charge of: $11.65 plus

A Demand Charge of:
$72.00 for the first 18 kilowatts of demand, and
$4.00 per kilowatt for all additional kilowatts of demand; plus

An Energy Charge of:
Summer 4.87 cents per kilowatthour for the first 300 kilowatthours per kilowatt of demand, and
2.99 cents per kilowatthour for all additional kilowatthours.

The summer rate will be applicable June 1 through September 30.

Winter 3.90 cents per kilowatthour for the first 300 kilowatthours per kilowatt of demand, and
2.03 cents per kilowatthour for all additional kilowatthours.

The winter rate will be applicable October 1 through May 31.

Minimum Monthly Bill effective January 1, 1998:

$83.65.

Gross Monthly Bill:

The net monthly bill, computed in accordance with the Net Monthly Rate; plus an amount of 4%, which amount will be deducted if the bill is paid on or before the gross date thereon.

SCHEDULE NO. 231

GENERAL SERVICE - DEMAND

Determination of Demand:

Demand, for any billing period, shall be the kilowatts as shown by or computed from the readings of the District's kilowatthour meter with a demand register, for the 15-minute period of Consumer's greatest use during such billing period.

If the demand, so determined, however, is less than 85% of the Consumer's highest 15-minute kilovoltampere demand, the kilowatt demand will be increased for the purposes of this schedule by 50% of the difference between 85% of the kilovoltampere demand and the demand as determined above.

Such demand must be equal to or greater than the larger of the following:

85% of the highest 15-minute power factor adjusted demand during the summer billing months of the preceding 11 months, or

60% of the highest 15-minute power factor adjusted demand during the winter billing months of the preceding 11 months, or

18 kilowatts.

Contract Period:

A minimum of one year.

Reconnection Charge:

If a Consumer whose service has been terminated has such service reconnected within 12 months of such termination, a reconnection charge equal to the minimum monthly charge for the preceding 12 months, or any part thereof, shall be collected by the District.

Service Regulations:

The District's Service Regulations form a part of this schedule.

District Level Payment Plan:

For Consumers meeting the eligibility requirements specified in the District's Service Regulations, the Consumer may elect to be billed on the District's Level Payment Plan.

Special Conditions:

Consumer shall furnish, if requested, suitable space on the Consumer's premises for the District's transforming equipment, and if required, suitable space for switching and/or capacitor equipment.

District shall not be required to furnish duplicate service hereunder.

Appendix D: Site Energy Data before/after Installation

Site Energy Data before Installation

Month	Days	Electricity				Gas				Total
		kWh	kWh/day	kW	Electricity Bill	Days	MMBtu	MMBtu/day	Fuel Bill	Total Bill
Aug. 00	27	332,640	12,320	769	$18,490	29	234	8.07	$702	$19,192
Sep.00	33	398,304	12,070	777	$20,673	30	498	16.60	$1,494	$22,167
Oct. 00	31	251,424	8,110	777	$13,400	31	1241	40.03	$3,723	$17,123
Nov. 00	29	227,232	7,836	539	$11,680	31	2831	91.32	$8,493	$20,173
Dec.00	31	192,672	6,215	346	$10,827	33	3816	115.64	$11,448	$22,275
Jan.01	31	141,696	4,571	283	$8,709	30	3957	131.90	$11,871	$20,580
Feb. 01	33	176,256	5,341	279	$10,145	33	3881	117.61	$11,643	$21,788
Mar. 01	28	150,336	5,369	270	$9,068	28	2502	89.36	$7,506	$16,574
Apr. 01	28	183,168	6,542	549	$10,432	30	1811	60.37	$5,433	$15,865
May,01	30	304,992	10,166	795	$14,743	29	1276	44.00	$3,828	$18,571
Jun. 01	33	383,616	11,625	782	$17,745	31	753	24.29	$2,259	$20,004
Jul. 01	31	412,128	13,294	848	$21,842	29	701	24.17	$2,103	$23,945
Annual		3,154,464	8621.62		$167,753		23,501	63.61	$70,503	$238,256
Peak			13,294	848						

Site Energy Data after Installation

Month	Days	Electricity				Gas				Total
		kWh	kWh/day	kW	Electricity Bill	Days	MMBtu	MMBtu/day	Fuel Bill	Total Bill
Aug.02	32	427,824	13463.71	827	$22,724	29	375.2	12.94	$1,576	$24,300
Sep.02	31	414,144	13251.19	1028	$23,452	30	881.2	29.37	$3,701	$27,154
Oct.01	28	342,576	11875.02	936	$19,182	29	1841.4	63.50	$7,734	$26,916
Nov.01	31	311,040	10208.46	700	$16,153	32	2141.4	66.92	$8,994	$25,147
Dec. o1	30	290,304	9585.75	680	$15,101	32	3675.3	114.85	$15,436	$30,537
Jan.02	33	105,408	3209.89	339	$8,255	30	2737.5	91.25	$11,498	$19,752
Feb.02	28	175,556	6090.54	498	$10,552	32	3008	94.00	$12,634	$23,186
Mar.02	30	124,272	4240.80	276	$8,597	29	2129.4	73.43	$8,943	$17,540
Apr.02	30	291,456	9400.15	763	$14,767	29	1451.4	50.05	$6,096	$20,863
May.02	31	261,072	8441.34	874	$14,311	32	1090.1	34.07	$4,578	$18,889
Jun.02	29	305,856	10502.55	1023	$17,505	29	461.1	15.90	$1,937	$19,442
Jul. 02	31	388,512	12737.70	958	$21,762	30	340	11.33	$1,428	$23,190
Annual		3,438,020	9417.26		$192,362		20,132	54.80	$84,554	$276,916
Peak			13,464	1028						

Note: the electricity energy data include the site utility data and fuel cell utility data.

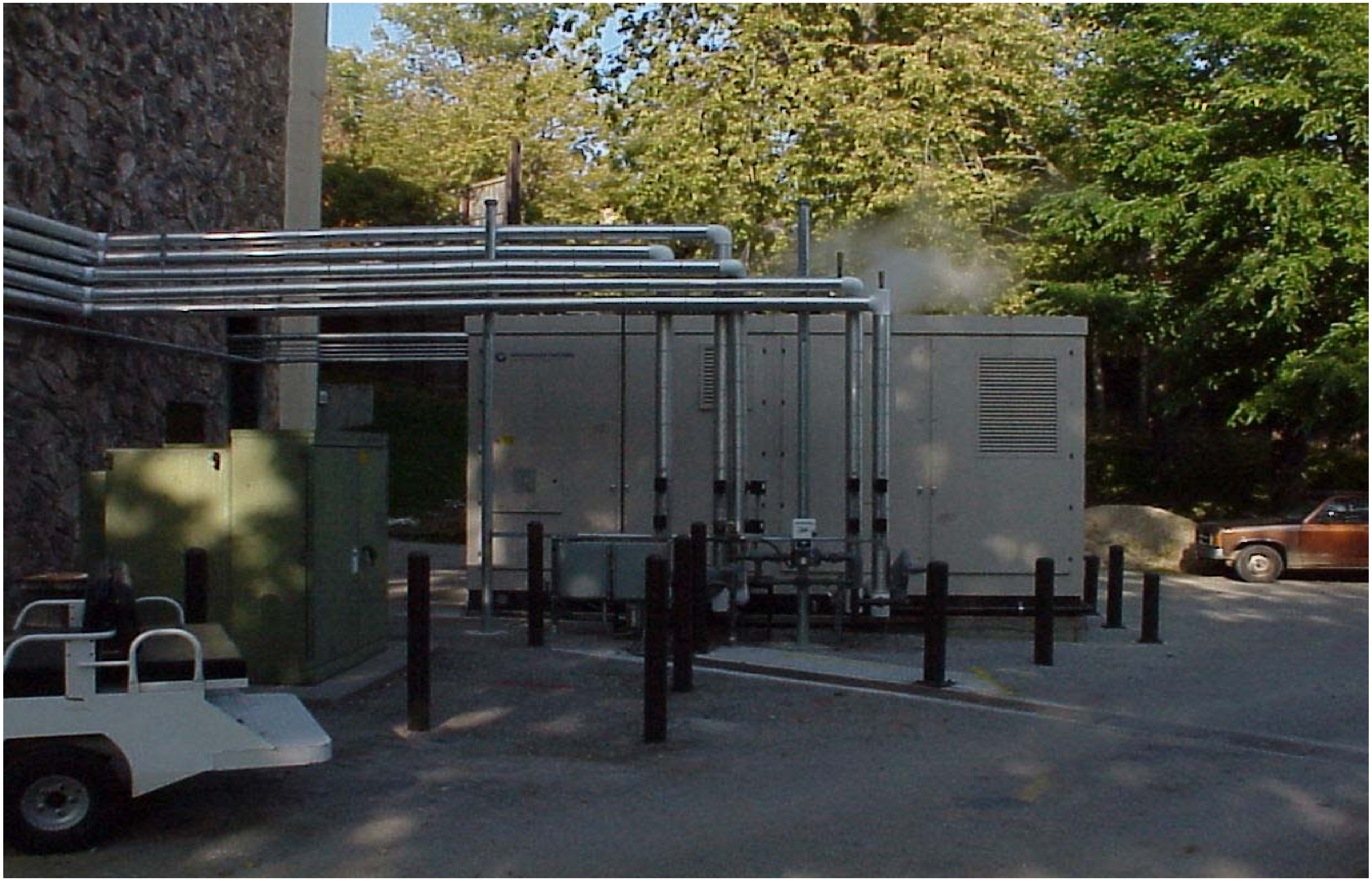
Comparison of the energy data before and after installation

Fuel	Before	After	Difference (%)
Electricity Consumption kWh/yr	3,154,464	3,438,020	9.2%
Gas Consumption MMBtu/yr	23,502	20,132	-14.3%

Discussion:

The difference of the total energy usage or total utility cost between the two years is a composite of the savings from the fuel cell application and the actual facility load changes. The electricity consumption comparison shows that the electricity load is increased after the installation. Therefore, the savings can not be determined by the simple direct utility data comparison method for this project. To accurately determine the energy and cost savings, OPPD installed a monitoring system which recorded the gas consumption, electricity output, and heat energy recovery (which are presented in the report).

Appendix E: Picture the Fuel cell System (Front)



Picture of the Fuel cell System (Back)

CERTIFICATION

The Omaha Public Power District (OPPD) certifies that it has complied in all respects with the grant under DE-FG26-00NT40957, Climate Change Fuel cell Program and that the related efforts required by that grant are now fully complete including twelve months of operation and submission of the final report herein supplied. Such report is in compliance with Paragraph 4 of DoE's Special Terms and Conditions for Research Projects Grants for Climate Change Fuel Cell Program.